DOCUMENT RESUME

ED 111 656 SE 019 524

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TITLE	Content Analysis of Selected Units of the First-Grade "Concepts in Science" Program.
INSTITUTION	Southwest Regional Laboratory for Educational Research and Development, Los Alamitos, Calif.
REPORT NO	SWRL-TN-2-72-59
PUB DATE	19 Dec 72
NOTE	85p.
EDRS PRICE	MF-$0.76 HC-$4.43 Plus Postage
DESCRIPTORS	*Concept Teaching; *Content Analysis; *Curriculum Evaluation; *Elementary School Science; *Instructional Materials; Primary Education; Science Course Improvement Project; Science Education; Scientific Concepts; Textbook Content
IDENTIFIERS	*Concepts in Science

ABSTRACT

To further evaluate a method of content analysis and aid in identifying scientific concepts appropriate at the elementary level, science material in a standard textbook series was examined. This paper reports and summarizes the analysis of sections of the California state-adopted textbook series, "Concepts in Science." The conceptual structure of the program is described and compared with the structure of the science program, Science Curriculum Improvement Study (SCIS). Problems encountered in the method of analysis are reported. Only about two-thirds of the chapters in the first-grade "Concepts in Science" program were analyzed, but it was shown that substantially more content was found in this program. (Author/EB)

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ED111656

SOUTHWEST REGIONAL LABORATORY
TECHNICAL NOTE

DATE: December 19, 1972

NO: TN-2-72-59

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To further evaluate a method of content analysis and aid in identifying scientific concepts appropriate at the elementary level, science material in a standard textbook was examined. The present paper reports and summarizes the analysis of sections of the California state-adopted textbook series, *Concepts in Science*. The conceptual structure of the program is described and compared with the structure of the previously analyzed *Science Curriculum Improvement Study*. Problems encountered in the method of analysis are reported.

SE 019 524

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Janis J. McClain

Analyses of elementary science programs may be used (1) to evaluate and modify a system of categorizing conceptual content, and (2) to help specify a domain of science concepts appropriate at the elementary school level. Smith and McClain (1972) reported an analysis of the content of selected *Science Curriculum Improvement Study* (SCIS) units. The SCIS approach, as pointed out by Smith (1972), emphasizes the processes of science as well as knowledge of content. Sections of the *Concepts in Science* program were selected for the present analysis because (1) it places much greater emphasis on content than processes, in contrast to SCIS, and (2) its wide usage (it is the California State adopted textbook series),

THE *CONCEPTS IN SCIENCE* PROGRAM

The *Concepts in Science* series is organized around a framework of six conceptual schemes representing energy, matter, organisms, and changes involving them. The present analysis covers the content developed in the first four of the six conceptual schemes in the first-grade *Concepts in Science* textbook and teacher's manual, permitting longitudinal examination of the development and use of the conceptual schemes. Three of the schemes covered deal with physical science:

1. When energy changes from one form to another, the total amount of energy remains unchanged.

2. When matter changes from one form to another, the total amount of matter remains unchanged.

3. The universe is in constant change.

The fourth conceptual scheme covered deals with a basic relation of biological science:

4. A living thing is a product of its heredity and its environment.

The two conceptual schemes not analyzed in this study were also biological in content. These latter two were not analyzed because the amount of resources necessary to complete them was excessive for the expected gain in information. Given the results for the first four schemes, it appeared that little more could be learned about the adequacy of the present method of analysis as applied to text materials. Furthermore, the SCIS analysis (Smith & McClain, 1972) had already provided examples of biological science concepts while the present analysis yielded numerous examples of physical science concepts.

A conceptual scheme is a broad relational category under which are subsumed a number of relational concepts and subconcepts which vary in degrees of complexity. For example, "A living thing is the product of its heredity and environment" is a conceptual scheme; underlying it are several relational concepts, from the simple, "Living things produce their own kind" to the more complex, "The characteristics of a living thing are laid down in a genetic code." For each conceptual scheme, the underlying relations are ordered

into six levels of complexity, with presumably simpler relations being introduced before proceeding to higher levels. Thus, the conceptual structure of the *Concepts in Science* series can be superficially summarized by a matrix of six conceptual schemes across six levels of complexity (corresponding to grade levels 1-6).

This contrasts with the structure of the SCIS program, which is organized principally along two divisions (physical science, biological science). Within these divisions individual units are centered around basic class or event concepts (e.g., "Material Objects" and "Organisms" are first-grade units; "Life Cycles" and "Systems" are second-grade units, etc.) rather than relational concepts. The two programs also differ in the basic approach used in presenting the content. SCIS places more emphasis on the direct interaction of the child with the materials he is studying; workbooks sometimes supplement the informal lessons in which content is presented, but textbooks are not used. The more traditional content oriented *Concepts in Science* program, on the other hand, is based primarily on textbook presentation.

PROCEDURES FOR CONTENT ANALYSIS

The basis for organizing scientific content was the categorization system which was described and modified in the report of the SCIS analysis (Smith & McClain, 1972). Briefly, this system classifies conceptual content into categories of class concepts, variable concepts, value concepts, event concepts, student/teacher action concepts, and several types of relational concepts, including correlational, comparative, and other relations. The other relational

concept category subsumes a diversity of relations. As a means of organizing these relations into more meaningful subgroupings, a modified version of the semantic relation types identified by Garvin, Brewer, and Mathiot (1967), was utilized. These types were identified by using a predication-typing technique to systematically analyze both scientific and nonscientific writings. The following relational types were used: constituency, empirical explanation (or causation), effect, usage, location, source, and requirement. Another category type, opposition, was added to account for a group of relations not easily categorizable into any of the Garvin et al., types.

The four conceptual schemes in the material analyzed are encountered in the first eight of the eleven units of the first-grade *Concepts in Science* textbook. Each unit is composed of several lessons; these lessons were analyzed individually in the present study. The sources of input for the analysis were the lesson activities described in the children's textbook and the "Introducing the Lesson" and "Developing the Concept" sections of the teacher's edition. As concepts were mentioned in a lesson, they were categorized and listed along with other previously specified information concerning their use (Smith & McClain, 1972). For each conceptual scheme, summary tables were then formed (see Appendix A). These tables were organized as follows:

Table 1: Class concepts and class variable concepts. Class concepts were organized into gross categories (e.g., constructs, objects, analytic concepts, etc.). Class concepts employed as values were indicated by listing variable names reflecting that usage.

Table 2: Event concepts.

Table 3: Descriptive variable and descriptive value concepts, organized into categories of quantitative and qualitative variables.

Table 4: Comparative (intradimensional) concepts, organized both by type of comparison (comparison between elements vs. comparison of the same element over time), and by the quantitative-qualitative distinction.

Table 5: Correlational (interdimensional) concepts.

Table 6: Other relational concepts.

Table 7: Student/Teacher action concepts.

RESULTS

Distribution of Concepts

For each conceptual scheme, Table 1 identifies the number of different concepts which occur in the above categories. Such a tabulation provides a superficial basis for comparing the types of concepts involved in each scheme. Since a number of concepts recurred in lessons representing several different conceptual schemes, a separate column totals the number of distinct (nonoverlapping) concepts across all conceptual schemes. These latter figures can also be compared with the number of first-grade SCIS concepts, which also appear in the table. Two considerations should be observed in comparing the two programs:

1. Analysis of the first-grade *Concepts in Science* program was not complete--approximately one-third of the chapters were not analyzed.

TABLE 1

NUMBER OF CONCEPTS IDENTIFIED

	SCIS Material Objects	SCIS Organisms	Total sistinct (nonoverlapping) SCIS concepts	"When energy changes from one form to another, the total amount of energy remains unchanged."	"When matter changes from one form to another, the total amount of matter remains unchanges."	"The universe is in constant change."	"A living thing is the product of its heredity and environment."	Total distinct (nonoverlapping) *Concepts in Science* concepts
Class Concepts (total)[1]	60	68	117	48	56	28	166	272
class value concepts	53	56	102	14	26	10	138	178
others	7	12	15	34	30	18	28	94
Event Concepts	4	8	10	0	1	3	8	10
Class Variable Concepts	18	15	27	6	8	4	43	57
Descriptive Variable Concepts	27	16	36	48	43	20	67	160
Descriptive Value Concepts (total)[2]	48	31	69	110	110	42	127	338
regular values	45	28	64	91	91	42	117	325
specific comparative values	3	3	5	19	27	0	10	55
Correlational Concepts	9	4	13	23	23	14	19	79
General Comparative Concepts	7	3	7	4	4	2	4	5
Other Relational Concepts	1	3	4	15	13	6	21	41
Student/Teacher Action Concepts	9	6	11	4	5	4	7	7

[1]Where sets of unspecified examples of classes were bracketed in Table 1, each set was counted once.

[2]Where sets of numbers [1, ...n] were included as values, each set was counted once; included one count for each case in which a variable is specified, but no particular values are indicated.

2. The two programs differ in the degree to which content is explicitly presented. Specification of content covered in the *Concepts in Science* teacher's manual and textbook is very explicit; the teacher's manual specifies actual questions to be asked and statements to be made. In the SCIS program while fundamental concepts are explicitly used, the usage of many other concepts, particularly variables and values, is often implicit. For example, children are often asked to describe or compare objects on some (any) variable; since no particular variable or values are specified there was no listing of them in the analysis. Thus, due to the nature of the different approaches of the two programs, it is expected that the number and frequency of descriptive variables, values, and comparatives identified would be somewhat less in SCIS.

Despite these two cautions, certain inferences can be drawn from these frequency distributions:

1. There is substantially more content in the first-grade *Concepts in Science* program. Even though one-third of the *Concepts in Science* content is not represented in the tables, the number of distinct concepts identified in every major category (classes, variables, values, relations), is much greater than the number of SCIS concepts identified.

2. The distribution of concepts in categories is considerably different in the two programs. In particular, the frequency of usage of higher level categories of concepts is greater in *Concepts in Science* than SCIS. Program differences are most dramatic in the proportion of concepts contained in the correlational and other relational categories. First-grade SCIS units emphasize comparison of objects and organisms, while the explicit usage of the other types of relational and organisms, while the explicit usage of the other types of relational concepts is infrequent. On the other hand, as implied in the conceptual structure of the program as a whole, *Concepts in Science* places its greatest emphasis on relational concepts.

CONCEPTUAL CONTENT OF CONCEPTS IN SCIENCE UNITS

Class Variables and Class Concepts

A number of class variable concepts (and certain class values associated with them) were used frequently in the units analyzed. These include:

Source of energy: food, fuel, (other values less emphasized)

Kind of force: gravity, lifting, magnetic

Form of matter: solid, liquid, gas

Form of water: ice, water, water vapor

Kind of plant:

Kind of animal:

Part of plant:

Part of animal:

Familial relation: parent, young

Time of day: day, night

Other class concepts given special emphasis in relation to the conceptual structure and/or frequently used include the following:

Constructs: energy, gravity, force, work, heat, light

Organism Concepts: plant, animal, egg, seed

Object Concepts: food, fuel, cloud, sun, earth

Analytic Concepts: investigation, part, stage

Perhaps the most important feature of this category of concepts is the presence of a number of advanced and theoretical constructs. Whereas the first-grade SCIS program is characterized by concrete, observable entities, abstract constructs based on complex relations between objects or events from an integral part of the conceptual makeup of *Concepts in Science*.

Except for the concept of "investigation," fundamental analytic concepts were not explicitly defined or emphasized in any particular way; the concepts "part" and "stage" were utilized as if they were already understood by the children and needed no further explication. No term analogous to the much emphasized SCIS concept of "property" was introduced.

Descriptive Variable and Value Concepts

As pointed out in the SCIS paper, many variables (e.g., amount of energy, amount of heat), are based on more fundamental ones (e.g., amount). Some of the variables emphasized in *Concepts in Science*

were also frequently used in the first year SCIS program. These are indicated with an asterisk in the list below.

temperature--hot, -er
cold, -er
warm, -er

amount of _____ *--more, less

velocity, rate of _____ --(e.g., doing work; evaporation; growth)
fast, -er
slow

number of _____*

strength of _____ --strong

ease or difficulty of _____ --(e.g., lifting, pushing)
easy, -er
hard, -er

illumination*--light
dark

elapsed time

size*--large, -er
big, -er
small
little

weight--heavy, -er
light

color

change in _____*--(e.g., temperature, size)

utilization of _____ (energy, force, heat)--has ____
uses ____
gets ____

motion, kind of motion--moving
not moving
rotates

direction--up
down

The chief difference between the two programs, aside from the numbers of concepts identified, is the complex, advanced nature of many *Concepts in Science* variables, as compared with the relative simplicity of those identified in SCIS. For example, whereas amount is used in SCIS to refer to quantity of observable entities (amount of liquid, amount of detritus in the sand), in *Concepts in Science* the variable is used to refer to some of the higher level constructs listed in the previous section (amount of energy used, amount of work done, amount of friction).

Comparative Concepts

The pattern of use of comparative concepts identified in this analysis is similar to that identified in the first-year SCIS program. The qualitative comparatives same and different were used in most sections analyzed and were particularly frequent in the biological chapters. The quantitative comparatives more than, less than, and the specific comparative -er values were extensively used throughout the program, while superlative -est values appeared infrequently. In general, comparisons between pairs of elements were much more frequent than comparisons of the same element over time. Those cases of comparisons over time were expressed primarily by the specific comparative -er form; the increase/decrease form found in SCIS was not used in the *Concepts in Science* sections analyzed.

Correlational Concepts

A large number of correlational concepts were identified; a total of 79 different correlations appeared in the first-grade *Concepts in*

Science sections analyzed, while only 13 were found in the entire first-grade SCIS program. A wide variety of variables, both qualitative and quantitative, were involved in the correlations. Again, aside from actual numbers of correlations, the most striking feature is the complex and advanced nature of many of the correlated variables, e.g., (amount of work done) and (amount of energy used), (whether object can be lifted) and (relative strengths of gravity and lifting force).

Other Relational Concepts

This category represents a modification of the Class-Class Relational Concepts category used in the SCIS analysis (see page 3). Again, frequency and variety of relations in the category were large in comparison with SCIS. Relations that were frequently used included causation, source, sequence, and effect. The causation relation was most often expressed as "A 'makes' B." In general, at least one of the two related members of the relation was event-like in nature, e.g., energy "makes" things move, heat "makes" ice melt. Source relations were generally expressed as "A (energy) comes from B (food)" or "X (car) gets A (energy) from B (fuel)." Source of energy was most frequently used; sources of light, food, water, and air were also dealt with. The sequence relation, represented by "A grows from/comes from/grows into B" was most utilized in chapters representing the biological scheme where developmental stages of plants and animals were studied. The effect relation is a broad classification composed principally of diverse types of specific active relationships between classes, e.g., "A eats B," "A pulls B."

Event Concepts

The definition and inclusion of concepts in this category was somewhat arbitrary. (See Modifications and Problems in Method of Analysis section.) In this analysis the most frequent uses of event concepts were biological in nature, e.g., growth, hatching, and sprouting. The broad concept change was also used in reference to a diverse set of variables, e.g., change in form of water, change in time of day.

Student/Teacher Action Concepts

Concepts in this category, particularly scientific process concepts, were systematically developed and emphasized in the Activity-Oriented SCIS program. In the *Concepts in Science* program, children were often asked to observe, describe, explain, and compare objects and events. However, the process terms themselves were never defined or emphasized in any way; program developers apparently assumed that these terms were already understood by children beginning the program.

DEVELOPMENT OF THE CONCEPTUAL SCHEMES

On detailed examination, the results of the analysis are quite informative about the conceptual organization underlying the textual presentation of content, both with respect to the interrelationships among concepts and their sequencing. A number of aspects of this conceptual organization reveal potentially serious sources of difficulty for conceptual development and learning in young children. Thus the analysis provides a valuable basis for critical evaluation

of the text as well as documenting its content. Some of the critical inferences which may be drawn based on the analysis are presented below.

As noted previously, a distinguishing feature of the first-grade *Concepts in Science* program is the utilization of advanced concepts. Constructs such as energy, work, and force, are basic to the conceptual structure of the program and are utilized in a number of important variables, values, and relations. Due to the difficult nature of these constructs themselves and the roundabout way in which they are developed in the program, there is question as to whether such constructs are understood to any meaningful extent by the first-grade child.

Many of the foundation constructs themselves are abstract and theoretical, often defined in their scientific usage only in terms of relations with other abstract theoretical constructs (the scientific concept "energy" for example, is defined in terms of the concept "work"). The ability of a six-year-old child to come close to a meaningful understanding of these higher order entities is intuitively questionable.

Moreover, the indirect method in which such constructs are introduced and developed in the *Concepts in Science* program would seem to add to the confusion. The foundation constructs are typically not defined in any sense. Energy, for example, introduced in the first lesson of the first-grade program, is not defined in that lesson nor is it defined in any later lesson in the text. The term is introduced to the child as the proper response to the question, "What makes the dog move?" "Energy makes the dog move." Later, the child is told

that in addition to causing motion, energy comes from food, fuel, electricity (also an undefined term), wind, and water; less energy is needed to move something when there is less friction; more energy is used per unit of time when something moves faster; the greater the amount of available energy, the greater the amount of work that can be done, etc. Parenthetically, from the way in which the concept is developed, it seems very likely that the child would erroneously conceptualize energy as some "substance" possessed by organisms and certain objects.

The point to be made is that, rather than defining energy after building upon the necessary conceptual underpinnings or foundations for its definition, the energy concept is merely presented in the context of various relations and the child is left with the burden of inferring its meaning. Several other constructs, such as friction and gravity, are treated in a similar manner. At face value, this indirect approach to teaching constructs would not seem productive of stable, well-grounded concepts. Furthermore, any confusion resulting from the lack of concept definition is considerably amplified, since these constructs form the basis for a multitude of variable and relational concepts which are fundamental to the conceptual structure of the program. Given the abstract nature of the constructs and the unsystematic way in which they are developed, it seems unlikely that many six-year-olds can grasp the correlation between amount of available energy and rate of doing work, or the opposition relation of lifting forces acting against gravity, or the Newtonian principle that every action results in an equal and opposite reaction.

In addition to the unsystematic development of advanced constructs, a number of more specific flaws were noted that will not be detailed here. In many cases, statements were made without any explication or foundation for their understanding. For example, the descriptive statement, "Mold plants cannot make their own food" is simply presented without any previous or subsequent development of the idea as if the first-grade child already had an understanding of the process of food manufacture in plants. In other cases, responses were elicited that clearly involved processes which most first-grade children have not developed; for example, the proper response to the question, "How much more energy is needed to lift four boxes of sugar than is needed to lift one?" implies multiplicative abilities that most six-year-old children have not learned.

It was also noticed that in many cases stated relational concepts and subconcepts which ostensibly expressed lesson content did not accurately represent that content. In some cases the concepts were more inclusive than the lesson content; e.g., the concept heading "Energy must be used to do work. Work is defined as a force acting through a distance." represented five lessons, none of which defined work in any way. In other cases, the concept simply did not characterize the lesson; one of several lessons summarized by the subconcept, "Day and night result from the rotation of the earth." dealt only with general information about astronauts leaving earth and traveling in space (later chapters, however, did illustrate the subconcept).

MODIFICATIONS AND PROBLEMS IN METHOD OF ANALYSIS

Certain unsolved problems encountered and reported in the SCIS analysis recurred in the course of the present analysis. These included:

1. The somewhat arbitrary distinction between class vs. descriptive variables and values;
2. a lack of clear distinction between event concepts and descriptive value concepts;
3. the lack of objective criteria for distinguishing between science concepts and more general concepts and between fundamental scientific concepts and nonessential examples.

Some of these problems were examined further in the present analysis and in some cases modifications in the method of analysis were made.

Event vs. Descriptive Value Concepts

The present analysis attempted to clarify the distinction between event concepts and descriptive value concepts by applying the following criteria:

1. If there was at least one specified alternative to the concept in question (other than the negation of the concept), then the concept was considered a descriptive value. For example, "melts" and "evaporates" are two alternatives of the variable "change of state." On the other hand, no alternative was specified for the concept "growth": therefore, it was listed as an event.

2. A second criterion involved the generality of application of the concept. If a concept was applicable to a diverse set of things, it was considered a value; if it was unique only to a very specific set of things, it was classified as an event. For example, the concept "rotation" applies virtually to anything that turns round as on an axis; therefore, it was listed as a value for the variable "type of motion." "Rising" and "setting" of the sun, however, were listed as events, since as used, the terms apply only to celestial bodies.

Another modification of the event concept tables was the addition of an event variable column which applied to sets of alternative concepts which were unique to specific kinds of things. For example, "rising" and "setting" are events subsumed under the variable "motion of sun relative to earth's horizon."

Class Variables and Values

Another general problem which arose in the course of the present analysis had to do with the conditions for identification of class variables and values. In the case of descriptive variables, if a descriptive value was used, an appropriate variable name was created for it and added to the variables list. However, in the case of class variables and values, there was no simple way of identifying when a class was used as a value, unless the variable name was actually presented along with alternative class values. Often mutually exclusive and parallel classes were identified, but were not used in conjunction

with a variable name. For example, the classes "mother" and "father" were used in describing pairs of birds. It was clear from their use together that these two classes represented alternative values for a "parent" variable, although the term "parent" was not used. On the other hand, while "plants" and "animals" certainly classify as alternative kinds of organisms or living things, their actual development in the program was separate, and thus they were not designated as class values by the reviewer. Due to the existence of other cases in which the decision was less clear-cut, there appears to be a need for more objective criteria for identifying class values.

CONCLUSION

No major problems were encountered in categorizing the program content using the set theoretic approach. The results provided a useful description of the nature of the content of the program and a basis for comparing the program with others similarly analyzed. More importantly, for present pruposes, the analysis provided a means of identifying problems which remain with the method itself. Some of the problems identified in the SCIS analysis have been satisfactorily solved, an important one being the subclassification of relational concepts. Others remain to be solved, including more adequate distinctions between descriptive value concepts and class or event concepts, and between general and specialized concepts. The former appears to require differentiating between the type of concept and the role it plays in a particular usage. The latter appears to require a judgment about the role of the concept in the discipline.

APPENDIX A

TABLE 1

CLASS/CLASS VARIABLE CONCEPTS

Class Concepts	Class Variable Concepts	Lesson
Conceptual Scheme: When energy changes from one form to another, the total amount of energy remains unchanged.		
Constructs		
energy		I (1-6), II (1-8), III (1-4, 8)
friction		II (2, 8)
force		III (3-8)
gravity	(kind of force)	III (1-8)
magnetic force	(kind of force)	III (6, 7)
wor[illegible]		II (5-8), III (7-8)
Organism/Organism Parts Concepts		
animal		II (5)
[Examples of animals--dog, horse, butterfly, snail, cat, bird, fish, elephant, ant]	kind of animal	I (1, 5, 6), II (4, 5, 7), III (2, 3)
[Examples of people--men, women, children, firemen, parachuter, farmer]		I (1-6), II (1, 3, 4, 6, 7), III (1, 2, 4)
muscles		I (3, 4)
Object/Object Parts Concepts		
spring (wound-up)	source of energy	I (1, 2, 6)
electricity	source of energy	I (2, 6), II (8), III (7)
fuel	source of energy	I (3, 6), II (3, 5, 7, 8)

Class Concepts	Class Variable Concepts	Lesson
gasoline	source of energy, kind of fuel	I (3, 6), II (3)
food	source of energy, kind of fuel	I (1-6), II (1, 3-5, 7, 8)
wind	source of energy	I (4, 6), II (3, 8)
water	source of energy	I (5, 6), II (8)
[Examples of spring-driven devices--clock, toy dog, record player, toy fire truck]		I (1, 2, 6)
[Examples of complex objects and tools driven by man--tricycle, bicycle, pencil sharpener, shovel, (hand) mower]		I (3, 6), II (5, 6, 8),
[Examples of objects driven by electricity--clock, record player, electric fan]		I (2, 6)
[Examples of fuel driven objects--motorbike, car, fire truck, airplane, crane, power shovel, power mower, tractor, truck]		I (3, 6), II (3-8), III (2, 8)
[Examples of wind driven objects--balloon, flag, pinwheel, sailboat]		I (4, 6), II (3)
[Examples of objects moved by water--leaves, twigs, raft]		I (5)
wheel		II (1, 6)
[Examples of objects on wheels--roller skate, piano on rollers, television set on rollers, stones in wagon, child in wagon, leaves in wheelbarrow]		II (1, 2, 8)
[Examples of objects not on wheels--skate moved on its side, piano, television set, stones on stone board, child in box, leaves in box]		II (1, 2, 8)

Class Concepts	Class Variable Concepts	Lesson
pedal		II (6)
gear		II (6)
chain		II (6)
pulley		II (7)
earth		III (2, 8)
[Examples of objects moved by gravity--apple, unsupported shelf, ball, chopped-off tree, rocks, parachute]		III (1, 8)
machine		II (5, 6), III (4)
[Examples of objects which can be moved by machines--steel girder]		III (4)
[Examples of simple objects moved by man--glass of milk, books, bales of hay, food, ball, arrow]		I (4), II (7), III (3, 4, 8)
magnet		III (6-8)
[Examples of objects that can be lifted by magnets--steel pins, scrap metal, paper clips, etc.]		III (6-8)
[Examples of objects that cannot be lifted by magnets--seeds, rubber bands, etc.]		III (6, 7)
[Examples of objects moved by a counteracting force--rocket, balloons]		III (5)
<u>Material Concepts</u>		
air		III (5)
gas		III (5)
metal	(kind of material)	III (6)

Class Concepts	Class Variable Concepts	Lesson
iron	(kind of material)/kind of metal	III (6)
steel	(kind of material)/kind of metal	III (6, 7)
Time Concepts		
time		I (2), II (3, 4)
week		II (4)
day		II (5)
Analytic Concepts		
investigation		II (1), III (5)
Conceptual Scheme: When matter changes from one form to another, the total amount of matter remains unchanged.		
Constructs		
heat		IV (6, 8, 9), V (1, 2, 5-7, 9)
gravity, force of gravity		V (2, 4)
Organism/Organism Parts Concepts		
plant		V (8)
animal		V (8)
Object/Object Parts Concepts		
container		IV (2)
[example of container--plastic bag]		IV (1, 2)

Class Concepts	Class Variable Concepts	Lesson
thermometer		IV (4, 5, 6, 9)
sun	source of heat	IV (4, 6, 8, 9) V (5, 6, 7, 9)
fire	(source of heat)	IV (8)
lamp	(source of heat)	V (5)
furnace	(source of heat)	V (5)
[Examples of wet objects--mittens, clothes, towels, hair, dishes, sidewalk]		IV (8)
[Examples of things kept in freezer compartments (unspecified)]	kind of thing kept in freezer compartments	IV (5)
[Examples of things which indicate a winter and summer (pond) scene--ice, snow, etc.]	things which indicate a winter and summer scene	IV (6)
droplet		V (1-4, 9)
drop		V (2-4, 9)
weather		V (3, 4, 8)
cloud		V (1-4, 7-9)
rain		V (4, 8, 9)
fog		V (3, 9)
snow		IV (9)
wind		V (8)
airplane		V (3)
<u>Materials/States of Matter</u>		
solid	(form of matter)	IV (1-5, 9) V (9)

Class Concepts	Class Variable Concepts	Lesson
liquid	(form of matter)	IV (2-5, 7, 9), V (1, 9)
gas	(form of matter)	IV (2, 7, 9), V (1, 9)
ice	form of water	IV (3-5, 9), V (9)
water	form of water	IV (1-5, 7-9), V (1-9)
water vapor	form of water	IV (7, 9), V (1, 2, 5, 7, 9)
[Examples of solids--rock, ice cream, butter]		IV (1, 2)
[Examples of liquids--melted ice cream, melted butter]		IV (1, 2)
[Example of gases--air]		IV (1, 2)
<u>Location Concepts</u>		
place (location)		IV (4-6, 8, 9) V (6)
[Examples of locations of different temperatures--freezer, windowsill, on stove, in refrigerator etc.]		IV (4, 5), V (6)
[Examples of water locations--swimming pool, wet playground, wet lawn, ocean, pond, lake]		VI (6), V (7, 9)
desert		V (8)
air		IV (7), V (1, 5, 7, 9)
sky		V (1, 3, 4, 8)
ground		V (4)

Class Concepts	Class Variable Concepts	Lesson
Time Concepts		
time		IV (4), V (2)
[Examples of specific times--8:00, 2:00, 5:00, etc.]	(time of day)	IV (4, 5), V (2)
morning	(time of day)	IV (5)
evening	(time of day)	IV (5)
day	(time of day)	V (5, 6)
night	(time of day)	IV (5)
winter	(season)	IV (6)
summer	(season)	IV (6)
Monday	(day of the week)	IV (7), V (5)
Tuesday	(day of the week)	IV (7)
Wednesday	(day of the week)	V (5)
Friday	(day of the week)	V (5)
yesterday		IV (5)
today		V (4, 6)
tomorrow		V (6)
week		V (6)
Analytic Concepts		
investigation		IV (6), V (6)

Class Concepts	Class Variable Concepts	Lesson
Conceptual Scheme: The universe is in constant change.		
Constructs		
light		IV (1, 3-8)
sunlight	(kind of light)	IV (4, 6, 7)
moonlight	(kind of light)	IV (6)
energy		IV (2)
Organism/Organism Parts Concepts		
astronaut		IV (2, 3)
Object/Object Parts Concepts		
sun	source of light	IV (1, 4-8)
[Other examples of light sources--flashlight]	source of light	IV (1, 3, 7)
earth		IV (1-8)
globe		IV (1, 7)
ball		IV (1, 2)
rocket		IV (2, 3)
capsule	part of rocket	IV (2, 3)
shadow		IV (4, 5, 8)
cloud		IV (4)
[Examples of things which do not let light through--cloud, cardboard, yardstick, people, houses]		IV (4, 5)
[Unspecified examples of things which let light through]		IV (4)

Class Concepts	Class Variable Concepts	Lesson
moon		IV (6-8)
[Examples of other sources of reflected light--mirror, white paper]		IV (7)
star		IV (8)
Material Concepts		
solid		IV (2)
Location Concepts		
space		IV (2, 3)
Time Concepts		
day	(time of day)	IV (1-3, 5-8)
night	(time of day)	IV (1-3, 6-8)
morning	time of day	IV (5, 8)
noon	time of day	IV (5, 8)
evening	time of day	IV (5, 8)
Analytic Concepts		
investigation		IV (7)
part		IV (1, 3, 6, 7)
Conceptual Scheme: A living thing is the product of its heredity and environment.		
Organisms/Organism Parts Concepts		
plant		VII (1-11)
seed	part of plant	VII (1-4, 7-8, 11) VIII (10)

Class Concepts	Class Variable Concepts	Lesson
tree		VII (9)
Examples of plants:		
lima bean	kind of plant/seed	VII (1, 2)
bean	kind of plant/seed	VII (3, 11)
radish	kind of plant/seed	VII (3)
cabbage	kind of plant/seed	VII (3)
carrot	kind of plant/seed	VII (3)
corn	kind of plant/seed	VII (3, 7)
beet	kind of plant/seed	VII (3)
geranium	kind of plant/stem	VII (4, 11)
pussy willow	kind of plant/stem	VII (4)
mold	kind of plant	VII (5, 6)
grass	kind of plant/seed	VII (7)
oats	kind of grass plant/seed	VII (7)
rice	kind of grass plant/seed	VII (7)
wheat	kind of grass plant/seed	VII (7, 11)
rye	kind of grass plant/seed	VII (7)
barley	kind of grass plant/seed	VII (7)
fruit	part of plant	VII (5, 6, 8, 11)
orange	kind of plant/fruit	VII (5, 8, 11)
apple	kind of plant/seed/fruit	VII (8, 11)

Class Concepts	Class Variable Concepts	Lesson
grapefruit	kind of plant/seed/fruit	VII (8)
cherry	kind of plant/seed/fruit	VII (8, 11)
pear	kind of plant/seed/fruit	VII (8, 11)
peach	kind of plant/seed/fruit	VII (8, 11)
plum	kind of plant/seed/fruit	VII (8)
watermelon	kind of plant/seed/fruit	VII (8)
oak	kind of plant/tree	VII (9, 11)
plant with burrs	kind of plant	VII (9)
dandelion	kind of plant	VII (9)
potato	kind of plant	VII (10, 11)
acorn	kind of seed	VII (9)
burrs	kind of seed	VII (9)
potato eye	part of (potato) plant	VII (10, 11)
seed pod	part of plant	VII (1, 3)
leaf	part of plant	VII (1, 3-5, 7)
root	part of plant	VII (3, 4)
stem	part of plant	VII (4, 5, 11)
flower	part of plant	VII (4, 8, 11)
animal		VII (9), VIII (2-9, 11, 15)
egg		VIII (1-6, 10, 11, 13-15)
parent		VIII (1-11, 13-15)

Class Concepts	Class Variable Concepts	Lesson
young ("baby")		VIII (1-11, 13-15)
adult		VIII (3, 4, 6, 7, 9, 14)
mother		VIII
father		VIII (10, 13)
male		VIII (13)
female		VIII (13)
pet		VIII (9)
Examples of animals		
bird	kind of animal	VIII (1, 2, 10, 11-15)
chicken	kind of animal/bird/egg	VIII (1, 2, 10, 11)
blue jay	kind of animal/bird/egg/nest	VIII (1, 10, 11, 12)
owl	kind of animal/bird	VIII (1)
duck	kind of animal/bird/egg	VIII (1, 11)
sea gull	kind of animal/bird	VIII (2)
turkey	kind of animal/bird	VIII (10)
hawk	kind of animal/bird	VIII (10)
eagle	kind of animal/bird	VIII (10)
mockingbird	kind of animal/bird/egg	VIII (10, 11)
oriole	kind of animal/bird/egg/nest	VIII (10-12)
sparrow	kind of animal/bird/egg/nest	VIII (10-12)

Class Concepts	Class Variable Concepts	Lesson
robin	kind of animal/bird/egg	VIII (10, 11, 13)
gold finch	kind of animal/bird/egg/nest	VIII (10-12)
cowbird	kind of animal/bird/egg	VIII (14)
warbler	kind of animal/bird/egg/nest	VIII (14)
canary	kind of animal/bird	VIII (15)
cardinal	kind of animal/bird	VIII (15)
reptile	kind of animal	VIII (2, 14)
turtle	kind of animal/reptile/egg	VIII (2, 5-7)
snake	kind of animal/reptile	VIII (2, 15)
lizard	kind of animal/reptile	VIII (2)
insect	kind of animal	VIII (3, 4, 6, 10, 14, 15)
grasshopper	kind of animal/insect	
moth	kind of animal/insect/ stage in life of moth	VIII (4)
caterpillar	kind of animal/insect/ stage in life of moth	VIII (4)
cocoon	stage in life of a moth	VIII (4)
dragonfly	kind of animal/insect/egg	VIII (6)
cricket	kind of animal/insect	VIII (15)
butterfly	kind of animal/insect	VIII (15)
fish	kind of animal/egg	VIII (5, 6, 15)
salmon	kind of animal/fish	VIII (5)

Class Concepts	Class Variable Concepts	Lesson
goldfish	kind of animal/fish	VIII (15)
frog	kind of animal/egg/(stage in life cycle of frog)	VIII (6, 15)
tadpole	kind of animal (stage in life cycle of frog)	VIII (6)
mammal	kind of animal	VIII (7-9, 14)
cow	kind of animal/mammal	VIII (7)
calf	kind of animal/mammal	VIII (7)
rabbit	kind of animal/mammal	VIII (7)
sow	kind of animal/mammal	VIII (7)
pig	kind of animal/mammal	VIII (7)
horse	kind of animal/mammal	VIII (7)
pony	kind of animal/mammal	VIII (7)
colt	kind of animal/mammal	VIII (7)
sheep	kind of animal/mammal	VIII (7)
lamb	kind of animal/mammal	VIII (7)
goat	kind of animal/mammal	VIII (7)
kid	kind of animal/mammal	VIII (7)
cat	kind of animal/mammal	VIII (7, 9)
gazelle	kind of animal/mammal	VIII (8)
lion	kind of animal/mammal	VIII (8)
bear	kind of animal/mammal	VIII (8)
kangaroo	kind of animal/mammal	VIII (8)
giraffe	kind of animal/mammal	VIII (8)

Class Concepts	Class Variable Concepts	Lesson
zebra	kind of animal/mammal	VIII (8)
kitten	kind of animal/mammal	VIII (9)
dog	kind of animal/mammal	VIII (9)
puppy	kind of animal/mammal	VIII (9)
mouse	kind of animal/mammal	VIII (15)
people	kind of animal	VII (9) VIII (6, 9, 12)
spider	kind of animal	VIII (3, 15)
worm, earthworm	kind of animal	VIII (4, 10, 13)
beetle	kind of animal	VIII (13)
shell	part of egg/(part of turtle)	VIII (1, 2, 5)
shell lining (membrane)	part of egg	VIII (1)
(the) white part	part of egg	VIII (1)
yolk	part of egg	VIII (1)
leg	(part of turtle/grasshopper/gazelle/frog/moth)	VIII (2-4, 6, 8)
head	(part of turtle)	VIII (2)
scale	(part of reptile)/(type of skin covering for animal, specifically reptiles)	VIII (2, 8, 15)
wing	(part of grasshopper)/part of moth/bird	VIII (3, 4, 10)
feeler or antenna	(part of grasshopper)/part of moth	VIII (3, 4)

Class Concepts	Class Variable Concepts	Lesson
skin	(part of caterpillar)/ part of gazelle	VIII (4, 8)
band	part of moth	VIII (4)
spot	part of moth/(part of sparrow egg)	VIII (4, 10)
gill	(part of fish)/(kind of breathing apparatus)	VIII (5, 6)
mouth	(part of fish)	VIII (5)
lung	(part of animal)/(kind of breathing apparatus)	VIII (6, 9)
tail	(part of tadpole)/part of gazelle/bird	VIII (6)
eye	(part of frog)	VIII (6)
ear	(part of gazelle)	VIII (8)
neck	(part of giraffe)	VIII (8)
hair	type of covering for animal	VIII (8)
feathers	type of covering for animal	VIII (8, 10)
fur	type of covering for animal	VIII (8)
horn	(part of gazelle)	VIII (8)
crest	(part of blue jay)	VIII (10)
bill	(part of bird)	VIII (10)
streak	(part of sparrow egg)	VIII (10)
back	(part of mockingbird)	VIII (10)
underside	(part of mockingbird)	VIII (10)
forehead	(part of gold finch)	VIII (10)

Class Concepts	Class Variable Concepts	Lesson
Object/Object Parts Concepts		
food		VII (1, 3, 6-9) VIII (1, 4, 9, 10)
meat		VIII (8)
milk		VIII (8)
sun		VII (3, 10)
magnifying glass		VII (5)
wind		VII (9)
nest		VIII (12, 13)
Material Concepts		
material		VIII (12)
water	(habitat for fish/ tadpoles), (what people, pets need to live)	VII (2-4, 7) VIII (5, 6, 9)
soil		VII (3, 4)
air	(what is breathed), (what people and pets need to live)	VII (5, 6, 9)
Location Concepts		
place		VII (10)
farm	(place where animals are raised)	VIII (7)
zoo	(place where animals are raised)	VIII (8)
Time Concepts		
winter	(season)	VIII (10)

Class Concepts	Class Variable Concepts	Lesson
spring	(season)	VIII (10)
morning	(time of day)	VIII (10, 13)
evening	(time of day)	VIII (10)
night	(time of day)	VIII (13)
Analytic Concepts		
part		VII (3, 4) VIII (1, 4)
investigation		VII (6, 10)
pair		VIII (3, 10)
cluster		VIII (3)
stage		VIII (4)
group		VIII (7)

TABLE 2

EVENT CONCEPTS

Event Concepts	Event Variable	Specified Variables Involved in Event	Classes Described Or Referred to	Lesson
Conceptual Scheme: When matter changes from one form to another, the total amount of matter remains unchanged.				
change		form of water	water/ice/water vapor	IV (3-5, 7-9) V (2, 4, 5, 7, 9)
		size of droplets of water	droplets/drops, water	
Conceptual Scheme: The universe is in constant change.				
(rising), to rise	(motion of sun relative to earth's horizon)	height of sun in sky, direction of sun	sun	VI (1)
(setting), to set	(motion of sun relative to earth's horizon)	height of sun in sky, direction of sun	sun	VI (1)
change		part of earth illuminated by sun	earth, sun	VI (1, 3, 5, 8)
		time of day position of shadow size of shadow	day, night	
Conceptual Scheme: A living thing is the product of its heredity and environment.				
growth, to grow		size	plants, e.g., corn; animals, e.g., horse; parts of plants, e.g., stem	VII (1-11) VIII(1-11, 13, 14)

Event Concepts	Event Variable	Specified Variables Involved in Event	Classes Described Or Referred to	Lesson
hatching, to hatch			eggs, birds, e.g., chicken; reptiles, e.g., turtles; insects, e.g., grass-hopper; fish, e.g., salmon	VIII (1-14)
laying (eggs), to lay (eggs)	(way of giving birth)		eggs; birds. e.g., chicken; reptiles, e.g., turtles; insects, e.g., grass-hopper; fish, e.g., salmon	VIII (1-14)
having live young	(way of giving birth)		mammals, e.g., cows	VIII (7, 8)
flying, to fly			insects, e.g., moth; birds, e.g., oriole	VIII (4, 10, 12-14)
feeding/eating, to eat			caterpillar; birds, e.g., sparrow	VIII (4, 8-10, 13, 14)
breathing, to breathe			fish, e.g., salmon; frog, tadpole; mammals, e.g., dog, people	VIII (5, 6, 9)
change		stage in life of moth/frog	moth, cocoon, caterpillar, egg	VIII (4, 6)

TABLE 3

DESCRIPTIVE VARIABLE/VALUE CONCEPTS

Descriptive Variable Concepts	Descriptive Value Concepts	Classes Described Or Referred To	Lesson
Conceptual Scheme: When energy changes from one form to another, the total amount of energy remains unchanged.			
Quantitative Variables			
(length of playing time without stopping)	plays for a long time without stopping (does not play for a long time without stopping)	electric record player, hand-driven record player	I (2)
(length of riding time without stopping)	rides for a long time without stopping (does not ride for a long time without stopping)	motorbike, bicycle	I (3)
(difficulty of riding)	easier to ride, harder to ride	motorbike, bicycle	I (3)
(amount of gasoline)	has gasoline has "run out" of gasoline	automobile, motorbike, gasoline	I (3)
(amount of stretch on rubber band pulling skates)	stretches slightly (stretches a lot)	rubber band pulling skates on wheels/not on wheels	II (1)
(difficulty of push or pull in moving object)	hard, easy, easier	objects on wheels/not on wheels; bales of hay lifted with pulley/ without pulley	II (1, 2, 7)
(amount of energy used)	more energy used less energy used	hand shovel, tractor; hand mower, power mower; man, tractor, horse; boy, boy on bicycle, truck; objects on wheels/not on wheels; children running/walking; elephant, ant, crane	II (1-8)

Descriptive Variable Concepts	Descriptive Value Concepts	Classes Described Or Reffered To	Lesson
roughness		ground	II (2)
(amount of friction)	less friction	box of rocks pulled by horse	II (2, 8)
(elasped time in covering distance)	same time for all takes longer	people, horses, airplanes	II (3, 4)
(velocity)	moves fast, faster, moves slowly	boy on bicycle, boy on foot, truck; children, cars, sailboats; man, horse, airplane	II (3, 4, 6)
(amount of energy used per unit of time)	uses more energy (per unit of time)	man, horse, airplane; boy (on foot), boy on bicycle, truck; plows pulled by tractor/horse/man	II (4, 6, 7)
(ability to do work)	can do more work	elephant, ant, crane	II (5)
(rate of doing work)	faster	hand shovel, power shovel; pushing leaves in box/in wheelbarrow; hand mower, power mower; tractor, shovel	II (5, 8)
weight	heavier, heavy too heavy for people to lift	loads; steel girders; cans	II (5) III (3, 4, 7)
size	tiny, bigger, big little	elephant, ant; magnets; hole dug by power shovel, hand shovel	II (5), III (7)
(amount of work done)	does more work	man, tractor, horse; newsboy on foot, newsboy on bicycle, newsman in truck; elephant, ant, crane; magnet, electric magnet; shovel, tractor	II (5-8) III (7)
(amount of available energy)	has more energy	boy, truck; horse, man airplane; elephant, crane, ant	II (4-6)

Descriptive Variable Concepts	Descriptive Value Concepts	Classes Described Or Referred To	Lesson
(number of bales of hay being lifted)	1, 4, 8	bales of hay	II (7)
(ease of self-motion)	easy to move (self) hard to move (self)	cat, child, airplane	III (2)
(difficulty of lifting)	harder to lift	objects--hay, book, blocks, steel girder	III (4)
(amount of force)	has enough force has more force, stronger (force)	machine, man; lifting force, force of gravity	III (4, 7)
(strength of magnetic force)	(has) strong pull, force (has) stronger pull	electric, nonelectric magnets	III (7)
(strength of magnetic force relative to gravity)	has enough force to overcome force of gravity does not have enough force to overcome force of gravity	magnets (electric, nonelectric)	III (7)
(relative strengths of lifting force and gravity)	gravity stronger than lifting force lifting force stronger than gravity	people, machines	III (4)
<u>Qualitative Variables</u>			
(life processes)	stays alive, breathes	dog	I (1)
(motion)	moving, not moving	water, wind, animals, people, objects driven by mechanical means, electric fuel, wind, moving water	I (1-6), II (1, 2)
(energy utilization)	has energy, uses energy, gets energy	animals, people, objects driven by mechanical means, electricity, fuel, wind, moving water	I (1-6), II (1-8), III (1-4, 8)

Descriptive Variable Concepts	Descriptive Value Concepts	Classes Described Or Referred To	Lesson
(kind of motion)	walks, runs, falls	people, animals, objects	I (1), II (3), III (1-3, 5, 8)
way in which things can be made to move	push, pull, lift, blow on, (plug in), (wind)	people, animals, objects	I (1,2,4,6) II (1,2,5, 7,8) III III (1-8)
(whether record player will play in woods)	will play in woods (will not play in woods)	hand driven record player electric record player	I (2)
(whether ___ needs moving water for its motion)	needs moving water to move (does not need moving water for motion)	inanimate simple objects, fish	I (5)
(whether object being moved is on wheels or not)	on its wheels, not on wheels/dragged	roller skate (on wheels or on its side), box of toys, piano, television, box of rocks	II (1, 2, 8)
(changes in motion)	starting to move, stops going up	objects on wheels, objects not on wheels; simple objects tossed into air	II (2), III (1)
mode of travel	on foot, on horseback, in covered wagon, in airplane	man, man on horseback, airplane, covered wagons pulled by horse	II (4)
way in which mail may travel	man on foot, man on horse, airplane	man, horse, airplane	II (4)
(ability to do work)	does work, can do work	man, tractor, horse; newsboy on foot, newsboy on bicycle, newsman in truck; elephant, ant, crane; magnets	II (5-8) III (7, 8)
way of making deliveries	boy on foot, boy on bicycle, truck	boy, bicycle, truck	II (6)
(means of lifting)	with pulley without pulley	bales of hay	II (7)

Descriptive Variable Concepts	Descriptive Value Concepts	Classes Described Or Referred To	Lesson
(direction of motion)	goes up, goes down toward center of earth, jumps up, falls down, goes in (a direction), goes in opposite direction, rises off the ground	examples of people; animals; objects moved by mechanical force, fuel, wind, gravity	III (1-5, 8)
(direction of pull)	pulls upward, pulls downward	lifting force, magnetic force, gravity	III (1-8)
(force utilization)	has force, use a force, loses force, needs force	people, machines, magnets	III (3, 4, 6, 7, 8)
(type of force)	lifting, pulling pushing	people, machines	III (3, 4, 8)
(whether ___ can be lifted)	can lift ___ cannot lift ___	man/machine lifting hay/steel girder	III (4)
(ability to be lifted by magnet)	can be/is lifted (by magnet) cannot be/is not lifted (by magnet)	examples of iron objects, steel objects, objects not made of iron or steel; examples of large metal objects, small metal objects	III (6, 7)
(electricity use in magnet	electricity turned on electricity turned off	electric magnet	III (7)
(kind of magnet)	can be "turned on and off" by electricity cannot be "turned on and off" by electricity	magnets	III (7)
(magnetic force utilization)	has magnetic force	magnets	III (7, 8)

Descriptive Variable Concepts	Descriptive Value Concepts	Classes Described Or Referred To	Lesson
Conceptual Scheme: When matter changes from one form to another, the total amount of matter remains unchanged.			
Quantitative Variables			
(texture)		water; bags of rocks/air/water	IV (1)
(shape retention)	has/keeps it own shape takes shape of the part of the container that holds it takes shape of the whole of the container that holds it	solids (rocks), liquids (water), gases (air)	IV (1, 2)
(wetness)	wet, dry	liquids (water), common objects	IV (2, 8)
(visibility)	cannot be seen can be seen	air, water vapor, cloud	IV (2, 7) V (1, 7)
(rate of melting)	melts first, melts next, does not melt at all	ice	IV (4)
(height of column on thermometer)	high, -er, low, -er	thermometer	IV (4, 6, 9)
(change in amount of heat)	gets more heat, is heated, loses heat	ice, water; water vapor	IV (4, 5, 9), V (1, 2)
temperature	hot, -er warm, -er, -est cold, -er, -est cool, -est higher temperature lower temperature freezing point warmer than freezing colder than freezing	air, water, ice, water vapor, metal sheet, stove (flame), inside of freezer, pond scene (in winter, summer)	IV (4-6, 8, 9) V (1, 2, 6, 7)

Descriptive Variable Concepts	Descriptative Value Concepts	Classes Described Or Referred To	Lesson
(change in temperature)	gets colder, cooler, is cooled gets hotter gets warmer temperature rises	ice, water, air	IV (5, 6) V (1)
(elasped time)	three hours by tomorrow by day after tomorrow by week from today by following morning		IV (5), V (2, 5, 6)
(illumination by sun)	in sunshine, in sunny place in shade, in shady place	place (location), e.g., sunny windowsill	IV (4, 6, 8) V (6, 7)
(number of __)	3, 10	drops of water	IV (7)
(amount of heat)	more heat, has plenty of heat	applied to wet objects, water/ice in jar puddles, pools, etc.	IV (5, 8) V (5-7)
(rate of evaporation/drying)	evaporates faster, dries faster dried up first dries more slowly	water, wet objects	IV (8), V (6, 7)
(amount of snow)		snow	IV (9)
(size)	tiny large small	water droplets, water drops	V (1, 2, 4)
(weight)	light weighs more heavy	water droplets, water drops	V (2, 4)
(strength of force of gravity)	greater	gravity applied to water drops/droplets	V (2)
(amount of evaporation of water)	some water will evaporate/has evaporated more water has evaporated water will not evaporate	water	V (2, 5, 6, 9)

Descriptive Variable Concepts	Descriptive Value Concepts	Classes Described Or Referred To	Lesson
(likehood of rain)	will/may rain will not rain	rain	V (4)
(amount of water vapor over jar)	more water vapor over jar	water in jar	V (5)
(amount of water in jar)	same less than nearly empty one cup	water in jars	V (5-6)
(distance from heat source)	near lamp far from lamp near fire far from fire on towel bar (far from iron) being ironed(near iron)	jar of water, wet objects	IV (8), V (5)
(amount of rain)	plenty of rain little rain more rain	rain	V (8)
(number of plants growing)	many plants growing few plants growing	plants	V (8)
(amount of water needed)	do not need much water	desert plants and animals	V (8)
(openness of container)	(lid on jar) (no lid on jar)	jars of water	V (9)
<u>Qualitative Variables</u>			
shape	roundish with edges like the bottom of bag fills the bag	bags filled with rocks (solid), water (liquid), air (gas); clouds (values unspecified)	IV (1, 2) V (1)
(taste)	cannot be tasted (has no taste)	air	IV (2)
(smell)	cannot be smelled (has no smell)	air	IV (2)

Descriptive Variable Concepts	Descriptive Value Concepts	Classes Described Or Referred To	Lesson
(change of state)	melts evaporates, changes from water vapor to droplets	water, ice	IV (3-5, 7-9), V (1, 2, 5-9)
(heat utilization)	has heat is heated gives heat gets heat	ice, water, lamp, furnace, stove, sun	IV (4, 5, 9) V (1, 5, 6)
(type of movement across sky)		clouds	V (1)
color	red	clouds, column of thermometer	IV (5) V (1, 3)
(whether ___ falls)	falls does not fall	drops of water, droplets of water	V (2, 4)
(position of airplane relative to clouds)	under clouds over clouds through clouds	airplane	V (3)
way of going through a cloud	walking driving flying	clouds	V (3)
way of looking down at top of clouds	from airplane from mountain top	clouds	V (3)
(presence of clouds)	clouds no clouds	clouds	V (4)
(kind of weather)	rainy cloudy clear sunny foggy		V (4, 8)
(where water vapor is going into the air)		water vapor, air	V (7)
(presence of rain)	rain is falling rain is not falling	rain	V (8)
(habitat)	place where there is plenty of rain	(most) plants/animals	V (8)

Descriptive Variable Concepts	Descriptive Value Concepts	Classes Described Or Referred To	Lesson
Conceptual Scheme: The universe is in constant change.			
Quantitative Variables			
(illumination of __)	light, is in daylight; dark, is in darkness; half light, half dark	parts of earth, earth (whole)	IV (1, 3, 6-8)
(opacity)	lets sunlight through does not let sunlight through	opaque, nonopaque objects	IV (4)
(length of __)	long	shadow	IV (5, 8)
(size of __)	small	shadow	IV (5, 8)
(height of sun in sky)	low in sky high in sky	sun	IV (5, 8)
(visibility)	easily seen not easily seen	objects in sunlight, moonlight	IV (6)
(whether __ is safe to look at directly)	safe to look at directly not safe to look at directly	sun, moon	IV (6)
(distance)	far away from earth/moon	sun	IV (7)
Qualitative Variables			
(whether day or night on __)	has day, is day-part; has night, is night, part; half day, half night	part of earth earth (whole)	IV (1, 3, 7)
(when __ shines)	shines by day shines by night	sun, moon	IV (1, 6, 7)
(kind of motion)	rotates	earth	IV (1, 5, 8)

Descriptive Variables Concepts	Descriptive Value Concepts	Classes Decribed Or Referred To	Lesson
(whether sun is shining on __)	sun is shining/there is sunlight; sun is not shining/there is no sunlight	parts of earth	IV (1, 3, 4)
(kind of light production)	shines reflects light	sun, moon	IV (1, 3, 4, 6, 7)
(direction of travel)	away from earth over earth into space around earth	rocket, astronaut	IV (2, 3)
(position of shadow-producing objects)	in the path of sunlight	clouds, other opaque objects	IV (4)
(whether shadow is made)	shadow is made shadow is not made	shadow	IV (4)
(position of shadow)	on one side of tree (and away from sun) on other side of tree (and away from sun) on both sides of tree	tree, shadow	IV (5, 8)
(direction of sun)	on one side (i.e. east) on other side (i.e. west)	sun	IV (5, 8)
(whether __ has light of its own)	has light of its own does not have light of its own	sun, moon, earth	IV (6, 7)
(relative position of part of moon)	toward sun away from sun toward earth away from earth	parts of moon	IV (7)

Conceptual Scheme: A living thing is the product of its heredity and environment.

Quantitative Variables			
number of seeds	1,...,n many few	seeds	VII (1), VIII (11)

Descriptive Variables Concepts	Descriptive Value Concepts	Classes Described Or Referred To	Lesson
(wetness)	wet, dry	seeds	VII (2, 7)
(elapsed time)	same day next day several days later		VII (2)
(number of different kinds of plants)	5	plants	VII (3)
(number of different kinds of seeds)	5	seeds	VII (3)
(change in size--growth)	grows bigger, grows larger does not grow	plants; caterpillar; caterpillar skin; young robins	VII (3), VIII (4, 13)
(amount of mold growth on fruit)	moldy, mold is growing; no mold is growing	mold; fruits, e.g., orange	VII (5, 6)
(illumination of __)	light dark	places where plants are growing	VII (5, 6, 10)
(temperature)	warm cold	places where plants are growing	VII (5, 6)
(rate of growth)	grows fast grows much faster grows sooner	mold; young robins; cowbirds, warblers	VII (6), VIII (13, 14)
(strength of __)	strong weak	plants; sparrow bill; gold finch bill	VII (10), VIII (10)
(hardness of shell of egg)	hard soft	shells of bird eggs/ reptile eggs/fish eggs	VIII (1, 2, 5)
(toughness of shell)	tough	turtle shell	VIII (2)
(length of feelers)	long	feelers of grasshopper	VIII (3)
(change in age)	becomes older	grasshopper	VIII (3)
(number of wings)	0, 2, 4,	wings of young grasshopper, wings of adult grasshopper; moth; chicken	VIII (3, 4)

Descriptive Variable Concepts	Descriptive Value Concepts	Classes Described Or Referred To	Lesson
(number of feelers)	2	feelers of grasshopper, moth, cricket	VIII (3, 4, 15)
size of __	large, -er, -est big is big enough for body small little tiny	bird eggs; grasshopper; caterpillar eggs; caterpillar skin; salmon; tadpole; sow; horse; rabbit; pig; colt; blue jay; turkey; hawk; chicken eagle; blue jay nest; gold finch nest; young cowbirds; young warblers	VIII (3-7, 10-12, 14)
(number of legs)	0, 2, 4, 6, 8	spider; insects, e.g., grasshopper; mammals, e.g., cow; birds, e.g., chicken; snake; frog	VIII (3, 4, 6-8, 15)
(number of stages in life of moth)	4	moth	VIII (4)
(amount of available food)	plenty of food	in caterpillar egg	VIII (4)
(brittleness of shell of egg)	somewhat brittle	caterpillar egg	VIII (4)
(texture)		rabbit	VIII (7)
(number of young __)	2, 3, 4, 6	rabbits; pigs; lions; bears; puppies; kittens; robins	VIII (7-9, 13)
(thickness of __)	thick	hair of lion/bear; bill of sparrow/gold finch	VIII (8, 10)
(length of __)	long, -er foot longer	giraffe's neck; blue jay; tail of mockingbird, tail of robin	VIII (8, 10)
number of spots		dog, puppies	VIII (9)
size of spots		dog, puppies	VIII (9)

Descriptive Variable Concepts	Descriptive Value Concepts	Classes Described Or Referred To	Lesson
(sharpness of __)	sharp	robin bill	VIII (10)
(how often eggs layed)	several times a year 3 or 4 times a year	robin sparrow	VIII (10)
(slenderness)	more slender	mockingbird, robin	VIII (10)
(brightness of color)	bright dull	feathers of mother and father gold finch	VIII (10)
(number of eggs laid)	3 to 6; 4 to 6; 4 to 9; 4; 5	blue jay, robin, gold finch, oriole, mocking-bird, sparrow	VIII (10, 12, 13)
(tightness of weave of nest)	compact, tightly woven; loose	gold finch nest blue jay nest	VIII (12)
(change in amount of strength)	grows stronger	young robins	VIII (13)
(age of __)	9 days old old enough to fly	young robins	VIII (13)
Qualitative Variables			
(germination)	sprouts does not sprout	seeds	VII (2)
(whether seed coat can be peeled)	can be peeled cannot be peeled	seed coat	VII (2)
shape		plants, e.g., radish	VII (3)
kind of leaves		plants, e.g., bean	VII (3)
(whether soil is watered)	is watered	soil	VII (3)
color of __	red pink green "pale" (green) colored black and white black	geranium flowers; stems of leaves of mold plant; plants; bands and spots of moth; cat, kitten; cow; blue jay; oriole (male), oriole (female); oriole egg; robin breast;	VII (4, 5, 10, 11)

Descriptive Variable Concepts	Descriptive Value Concepts	Classes Described Or Referred To	Lesson
color of __ (cont.)	blue; orange and black; brown, yellow, and white; dull white with streaks of brown and gray; brick-red; white with yellowish-green brown, or black spots; yellow; olive green and pale yellow; gray; white	robin bill; sparrow egg; warbler; gold finch (female), gold finch (male); back of mocking-bird, underside of mockingbird	
(whether or not plant makes own food)	cannot make own food	mold plants	VII (6)
(whether fruit touches fruit that is moldy)	touches moldy fruits does not touch moldy fruits	fruits, e.g., orange; mold	VII (6)
(whether __ spreads)	grows only on fruit on which it is already growing spreads from one food to another	mold	VII (6)
(whether __ is used for food)	is used for food is not used for food	grass plant seeds; fruit seeds	VII (7, 8)
(ways in which seeds are carried)	by animals by people by wind	seeds	VII (9)
(way of giving birth to young)	lays eggs has live young	birds; insects, e.g., dragonfly; fish, e.g., trout; reptiles, e.g., turtle; frog; mammals, e.g., sheep	VII (1, 2, 5-7, 10)
way __ uses legs to swim		turtle	VIII (2)
how __ moves (kind of motion)	walks runs jumps	turtle; caterpillar; mammals, e.g., horse	VIII (2, 4, 5, 7)
(way __ gets food)		caterpillar	VIII (4)
(location of gills)		gills of salmon	VIII (5)

Descriptive Variable Concepts	Descriptive Value Concepts	Classes Described Or Referred To	Lesson
(whether __ can take air from water)	can take air from water cannot take air from water	fish, humans	VIII (5)
(habitat)	can live in water can live out of water	fish, turtle	VIII (5)
(whether __ has shell)	has shell	eggs, seed	VIII (5)
(whether __ has beginning of new living thing)	has beginning of new living thing	egg, seed	VIII (5)
(whether __ has food early growth of living thing)	has food for early growth (of new living thing)	egg, seed	VIII (5)
(time of year when __ born)	born in spring	four-legged animals, e.g., calf	VIII (7)
(kind of food eaten by __)		rabbits	VIII (7)
(kind of marking of __)	striped coat	cow, zebra	VIII (7, 8)
(whether __ has horns)	has horns	gazelle	VIII (8)
pattern of spots		dog, puppies	VIII (9)
kind of dog	spotted	dog, puppy	VIII (9)
(direction of flight)	flys to warm places flys to cooler places	orioles	VIII (10)
(where nest built)	on ground in tufts of grass in bushes in low trees	sparrow nest	VIII (12)
(whether bird makes a nest)	makes a nest does not make a nest	cowbird, warbler	VIII (14)
(whether __ eggs need to be kept warm)	need to be kept warm to hatch do not need to be kept warm to hatch	cardinal, frog, butterfly	VIII (15)

TABLE 4

COMPARATIVE (INTERDIMENSIONAL) CONCEPTS

Comparative Concepts	Descriptive Or Class Variable Upon Which Based	Classes Referred To	Lesson
Conceptual Scheme: When energy changes from one form to another, the total amount of energy remains unchanged.			
COMPARISONS BETWEEN ELEMENTS			
Qualitative Comparisons			
same, alike	elasped time	children exercising rapidly/slowly;	II (3), III (7)
	(other unspecified variables)	actions of electric/ nonelectric magnets	
different	(unspecified variables)	actions of electric/ nonelectric magnets	III (7)
Quantitative Comparisons			
more than, (value + -er)	difficulty of riding (harder to ride)	bicycle, motorbike;	I (3),
	amount of energy used	cars, sailboats, people; airplanes, horses, people; objects on wheels/not on wheels; crane, elephant, ant; truck, boy on bicycle, boy; tractor, horse, man; power mower, girl pushing hand mower; hand shovel, tractor,	II (1-8) III (4, 7)
	velocity (moves faster)	cars, sailboats, children; airplane, horse, man; truck, boy on bicycle, boy on foot;	
	rate of doing work (faster)	hand shovel, power shovel; tractor, shovel; power mower, hand mower; pushing leaves in wheelbarrow/ in box; crane, elephant, ant;	

Comparative Concepts	Descriptive Or Class Variable Upon Which Based	Classes Referred To	Lesson
	amount of available energy amount of energy used per unit of time amount of work done size of hole dug (bigger) weight (heavier) ability to do work difficulty of lifting (harder to lift) amount of force (stronger force) strength of magnetic force (stronger pull)	airplane, horse, man; truck, boy; airplane, horse, man; plows pulled by tractor/ horse/man; boy on foot, boy on bicycle, truck; tractor, horse, man; truck, boy on bicycle, boy on foot; crane, elephant, ant; electric manget, (regular) magnet; shovel, tractor, power shovel, (hand) shovel; loads lifted by crane, elephant, ant; crane, elephant, ant; objects (differing in weight); machine, man; lifting force, force of gravity; electric, nonelectric magnets	
less than, (value + -er)	difficulty of riding (easier to ride) difficulty of push or pull in moving object (easier) amount of energy used amount of friction	motorbike, bicycle; objects on wheels, not on wheels; ant, elephant, crane; rocks on wheels/on stone board	I (3), I II (1, 2, 5)
Conceptual Scheme: When matter changes from one form to another, the total amount of matter remains unchanged.			
COMPARISONS BETWEEN ELEMENTS			
Qualitative Comparisons			
same	amount of water in jar	jars of water	V (5, 6)

Comparative Concepts	Descriptive Or Class Variable Upon Which Based	Classes Referred To	Lesson
Quantitative Comparisons			
less than, (value + -er)	amount of water in jars	jars of water	IV (6, 9), V (5, 6)
	temperature (colder)	locations (e.g., shade, sun), jars of water/ice	
	height of column of thermometer (lower)	thermometers (in different locations)	
more than, (value + -er)	amount of water vapor over jar	water vapor over jars of water in different locations;	IV (2, 4, 8, 9), V (2, 5-7)
	amount of evaporation	water (in different locations);	
	rate of drying (dries faster)	wet objects (in different locations); heat	
	amount of heat	applied to wet objects, jars of ice/water;	
	rate of evaporation (evaporates faster)	water in jars, puddles of water;	
	weight	drops/droplets of	
	strength of force of gravity (greater)	water; drops/droplets of water	
	temperature (warmer, hotter)	locations (e.g., shade, sun), jars of water/ice;	
	height of column of thermometer (higher)	thermometers (in different locations)	
(value + -est)	temperature (warmest, coolest, coldest)	locations in room	IV (8)
COMPARISONS OVER TIME (SAME ELEMENT)			
Quantitative Comparison			
more than, (value + -er)	change in amount of of heat (gets more heat)	ice/water	IV (4, 5), V (8)
	change in temperature (gets hotter, warmer)	ice/water	
	amount of rain	locations receiving varying amounts of rain	

Comparative Concepts	Descriptive Or Class Variable Upon Which Based	Classes Referred To	Lesson
less than, (value + -er)	temperature (colder) change in temperature (gets colder) amount of water	ice/water ice/water water on pan	VI (5), V (2)
Conceptual Scheme: The universe is in constant change.			
COMPARISONS BETWEEN ELEMENTS			
Qualitative Comparisons			
same, alike, resembles	part of earth illuminated by sun (unspecified variables)	parts of earth; sun, moon; moon mirror	IV (1, 6, 8)
different	(unspecified variables)	sun, moon	IV (6)
COMPARISONS OVER TIME (SAME ELEMENT)			
Qualitative Comparisons			
different	height/position of sun	sun	IV (1)
Conceptual Scheme: A living thing is the product of its heredity and environment.			
COMPARISONS BETWEEN ELEMENTS			
Qualitative Comparisons			
same, alike, like	kind of leaf shape of leaf kind of plant	leaves leaves plant grown from piece of stem/plant from which piece of stem was taken	VII (3, 4, 8) VIII (1-11, 13)

Comparative Concepts	Descriptive Or Class Variable Upon Which Based	Classes Referred To	Lesson
	whether __ has shell	egg, seed	
	whether __ has beginning of new living thing	egg, seed	
	whether __ has food for early growth of living thing	egg, seed	
	kind of animal	parent animal (e.g., sow), young animal (e.g., pig)	
	kind of legs/ears/tail/skin	parent gazelle, young gazelle	
	unspecified variables	fruit seeds; mother bird, father bird (of given species, e.g., robin); parent animal, young animal (of given species, e.g., chicken)	
different	kind (species) of of animal	sea gull, snake, turtle lizard	VII (8, 10), VIII (2, 3, 9)
	color of fur	mother cat, kitten	
	(unspecified variables)	fruit seeds; potato plants grown in light/dark; parent animal, young animal (of given species, e.g., chicken)	
Quantitative Comparisons			
more than, (value + -er)	rate of growth (grows sooner)	mold on fruits that are/are not already moldy;	VII (6), VIII (10, 14)
	size (larger)	birds, e.g., turkey, blue jay;	
	slenderness	mockingbird, robin;	
	length of tail (longer)	tail of mockingbird, tail of robin;	
	rate of growth (grows much faster)	cowbirds, warblers	

Comparative Concepts	Descriptive Or Class Variable Upon Which Based	Classes Referred To	Lesson
(value + -est)	size (largest)	birds, e.g., blue jay, oriole	VIII (10)
COMPARISONS OVER TIME (SAME ELEMENT)			
Quantitative Comparisons			
more than, (value + -er)	change in size (bigger/larger)	plants, e.g., corn; animals, e.g., caterpillar, young robins	VII (3), VIII (3, 4, 13)
	change in age (older)	grasshopper	
	change in amount of of strength (stronger)	young robins	

TABLE 5

CORRELATIONAL (INTERDIMENSIONAL) CONCEPTS

Related Variables		Classes Referred To	Lesson
Conceptual Scheme: When energy changes from one form to another, the total amount of energy remains unchanged.			
(amount of gasoline)	(motion)	fuel driven objects, e.g., car, motorbike	I (3)
(difficulty of pulling rubber band attached to roller skate)	(amount of stretch on rubber band pulling roller skate)	roller skate	II (1)
(amount of energy used to move object)	(difficulty of push or pull in moving object)	roller skate, box of toys, piano, television	II (1)
(difficulty of push or pull in moving object)	(whether object being moved is on wheels or not)	roller skate on wheels/on its side, box of toys, piano, television set, stones	II (1, 2)
(amount of energy used to move object)	(whether object being moved is on wheels or not)	roller skate on wheels/on its side, piano, television set, box of toys, child, stones	II (1, 2)
(amount of energy used to move object)	(amount of friction in moving object)	stones in wagon/ on stone board	II (2)
(whether object being moved is on wheels or not)	(amount of friction in in moving object)	stones in wagon/ on stone board, roller skate on wheels/on its side	II (2, 8)

Related Variables		Classes Referred To	Lesson
(difficulty of push or pull in moving object)	(amount of friction in moving object)	rocks in wagon/ on stone board	II (2, 8)
(amount of energy used per unit of time)	(velocity)	children, sailboats, cars; man, horse, airplane	II (3, 4)
(mode of travel)	(elapsed time in covering distance)	man, horse, airplane	II (4)
(ability to do work)	(amount of available energy)	elephant, crane, ant	II (5)
(amount of work done)	(amount of energy used)	elephant, crane, ant	II (5, 7, 8)
(rate of doing work)	(amount of available energy)	newsboy on foot, newsboy on bicycle, truck	II (6, 8)
(means of lifting object)	(difficulty of lifting or pulling in moving object)	bales of hay lifted with/ without use of pulley	II (7)
(ease of self-motion)	(direction of motion [up or down])	cat, people	III (2)
(whether __ can be lifted)	(relative strengths of gravity and lifting force)	hay, steel girder, book, desk	III (4)
(ability of object to be lifted by magnet)	(material object is made of)	objects made of iron, steel, other materials	III (6)
(size of magnet)	(ability of given object to be lifted by magnet)	small/large metal object; small/large magnets	III (7)
(ability of object to be lifted by magnet)	(strength of magnetic force relative to gravity)	metal objects, e.g., pins, cans, heavy scrap metal	III (7)

Related Variables		Classes Referred To	Lesson
(weight of object)	(ability of object to be lifted by magnet	magnet metal objects, e.g., pins, cans, heavy scrap metal	III (7)
(strength of magnetic force)	(electricity used in magnet)	electric magnet	III (7)
(strength of magnetic force used)	(amount of work done)	electric/non-electric magnets; mental objects	III (7)
(kind of magnet used)	(amount of work done)	electric/non-electric magnets	III (7)
Conceptual Scheme: When matter changes from one form to another, the total amount of matter remains unchanged.			
(rate of melting)	(amount of heat)	water/ice	IV (4)
temperature	(height of column on thermometer)	thermometer	IV (4, 6, 9)
(amount of heat)	temperature	water/ice	IV (5)
(change in temperature)	(change in amount of heat)	water/ice	IV (5)
(season)	temperature	winter pond scene, summer pond schene	IV (6)
(amount of heat)	(distance from heat source)	wet objects;	IV (8)
(amount of heat)	(illumination by sun)	wet objects; sun	IV (8)
(distance from heat source	(rate of drying)	wet objects; fire	IV (8)
(illumination by sun)	(rate of drying)	wet objects; sun	IV (8)
(amount of snow)	(temperature)	snow (in three pictured scenes)	IV (9)

Related Variables		Classes Referred To	Lesson
(change of state)	(change in amount of heat)	ice/water, water vapor	IV (4, 5, 9), V (9)
(illumination of sun)	temperature	air in sunny/ shady places	IV (4, 6), V (6)
(illumination)	(amount of heat)	air in sunny/ shady places	IV (8), V (6)
(amount of heat)	(rate of evaporation/ drying)	water, wet object	IV (8), V (6, 7)
(strength of force of gravity)	(weight of __)	water drops/ droplets	V (2)
(size of __)	(weight of __)	water drops/ droplets	V (2)
(whether __ falls)	(strength of force of gravity on __)	water drops/ droplets	V (2)
(elasped time)	(amount of evaporation)	water	V (2, 5)
(likelihood of rain)	(presence of clouds)	rain, clouds	V (4, 8)
(amount of heat)	(amount of evaporation)	water	V (5)
(amount of heat)	(amount of water vapor over jar)	water vapor	V (5)
(amount of rain)	(number of plants growing)	rain; plants	V (3)
(openness of container)	(amount of evaporation of water)	water in open/ closed jar	V (9)
Conceptual Scheme: The universe is in constant change.			
(whether sun is shining on __)	(illumination of __)	parts of earth	VI (1, 3)
(direction of sun)	time of day	sun; morning, evening	VI (1, 5)

Related Variables		Classes Referred To	Lesson
(whether sun is shining on __)	(whether day or night on __)	parts of earth; day, night	VI (1, 7)
(illumination of __)	(whether day or night on __)	parts of earth; day, night	VI (3)
(whether sun is shining on __)	(whether shadow is made)	parts of earth; shadow	VI (4)
(whether shadow is made)	(opacity of object in path of light)	shadow; opaque/ nonopaque objects	VI (4)
time of day	(height of sun in sky)	morning, noon, evening; sun	VI (5, 8)
time of day	(direction of sun in sky)	morning, noon, evening; sun	VI (5, 8)
(direction of sun in sky)	(position of shadow)	sun; shadow	VI (5, 8)
(height of sun in sky)	(length/size of shadow cast)	sun, shadow	VI (5, 8)
time of day	(position of shadow)	morning, noon, evening; shadow	VI (5, 8)
time of day	(length/size of shadow cast)	morning, noon, evening; shadow	VI (5, 8)
(kind of light)	(visibility)	objects in moonlight/sun-light	VI (6)
(illumination of part of moon)	(relative position of part of moon)	moon	VI (7)
Conceptual Scheme: A living thing is the product of its heredity and environment.			
(wetness of seed)	(germination)	seed	VII (2)
(wetness of seed)	(whether seed coat can be peeled)	seed; seed coat	VII (2)

Related Variables		Classes Referred To	Lesson
kind of seed	kind of plant grown from seed	seeds, e.g., corn; plants, e.g., corn	VII (3, 7-9, 11)
kind of plant	kind of stem from which plant is grown	geranium/pussy willow stems and plants	VII (4, 11)
(amount of mold growth on fruit)	(temperature)	mold	VII (5, 6)
(amount of mold growth on fruit)	(illumination of place where mold is growing)	mold; light	VII (5, 6)
kind of plant	kind of plant "made" from plant	mold	VII (6)
(rate of mold growth)	(whether fruit touches fruit that is moldy)	mold; fruit	VII (6)
(illumination of place where plant is growing)	(strength of plant)	plant; light	VII (10)
(illumination of place where plant is growing)	color of plant	light; plant	VII (10)
(kind of parent animal)	(kind of young animal hatched from parents egg or born "live" from parent)	birds, e.g., chicken; reptiles, e.g., snake; insects, e.g., grasshopper fish, e.g., salmon; mammals, e.g., cow	VIII (1-11, 14, 15)
(hardness of shell of egg)	(kind of animal)	birds, reptiles; eggs	VIII (2)
(number of wings)	(whether parent or "young")	wings; parent grasshopper, young grasshopper	VIII (3)
(direction of flight of __)	(season)	oriole, robin; winter, spring	VIII (10)

Related Variables		Classes Referred To	Lesson
(color of __)	(parent/sex of __)	oriole, gold finch	VIII (10)
(kind of bird)	(kind of nest built by bird)	birds, e.g., sparrow	VIII (12)
(size of bird and its eggs)	(size of nest bird needs)	birds, e.g., blue jay	VIII (12)
(number of legs of young __)	(number of legs of parent __)	cricket, snake	VIII (15)
(kind of skin of young __)	(kind of skin of parent __)	snake	VIII (15)

TABLE 6

OTHER RELATIONAL CONCEPTS

Relational Concepts	Members of the Relation	Lesson
Conceptual Scheme: When energy changes from one form to another, the total amount of energy remains unchanged.		
Causation (Empirical Explanation) Relations		
A makes B	A - energy B - people/things move	I (1-6), II (1, 8)
	A - food B - people/animals move	I (1, 6)
	A - electricity B - (electrically driven objects, e.g., record player) move	I (2, 6)
	A - fuel/gasoline B - (fuel driven objects, e.g., car) move	I (3, 6)
	A - wind B - (objects, e.g., flag) move	I (4, 6)
	A - water B - (objects, e.g., leaves) move	I (5, 6)
	A - gravity B - (objects, e.g., apple) move down/move toward the center of the earth/fall/stop going up	III (1-5, 8)
	A - air rushing out of balloon/air rushing downward B - balloon go in opposite direction (from the air)/ balloon go up	III (5)
	A - Gases pushing out of rocket/gases pushing downward B - rocket go in opposite direction (from gases)/rocket go up	III (5)

Relational Concepts	Members of the Relation	Lesson
A (causes/results in) B	A - every action B - an equal and opposite reaction	III (5)
A causes B	A - friction B - wear on surfaces that rub together	II (2)
Requirement Relations		
without A, there is no B	A - energy B - motion (of people or things)	I (1)
	A - electricity B - movement of (electrically-driven objects, e.g., record player)	I (2)
	A - fuel/gasoline B - movement of (fuel-driven objects, e.g., car)	I (3)
	A - wind B - movement of (wind-driven objects, e.g., balloon)	I (4)
	A - winding of spring-driven objects B - movement of (spring-driven objects, e.g., record player)	I (2)
it takes A to B	A - energy B - make things move	I (4, 6), II (1, 8), III (2)
A must be used to B	A - energy B - make things go up/lift things	II (7), III (3)
	A - energy B - work against gravity	III (2, 8)
	A - force B - work against/overcome gravity	III (3, 8)

Relational Concepts	Members of the Relation	Lesson
Source Relations		
A comes from B	A - energy B - electricity; wound-up spring, food, fuel/gasoline, wind moving water	I (1-6)
X gets A from B	X - (spring-driven objects, e.g., clock) A - energy B - wound-up spring	I (1, 2, 6)
	X - (electrically-driven objects e.g., record player) A - energy B - electricity	I (2, 6)
	X - (fuel-driven objects, e.g., car) A - energy B - fuel/gasoline	I (3, 6), II (3-8), III (2, 8)
	X - (objects moved by wind, e.g., flag) A - energy B - wind	I (4, 6), II (3)
	X - (objects moved by water, e.g., leaves) A - energy B - moving water	I (5)
	X - animals, people A - energy B - food	I (1-6), II (1, 3-5, 7, 8)
Effect Relations		
A acts on B	A - gravity; lifting force; magnetic force B - people; things, e.g., book; metal things, e.g., paper clips	III (4, 6)
A pulls B	A - force B - people, things, e.g., hay	III (3, 4, 8)
	A - gravity B - people/downward/things, e.g., book downward	III (1-5, 7, 8)

Relational Concepts	Members of the Relation	Lesson
A lifts B	A - magnet B - things made of iron/steel	III (6-8)
Opposition Relations		
A pulls/pushes/works against B	A - lifting force B - gravity	III (2, 4, 8)
in lifting objects, A acts in the opposite direction to B	A - magnetic force B - gravity	III (6)
in lifting objects, A overcomes B	A - lifting force/magnetic force B - gravity	III (3, 4, 7, 8)
A moves in the opposite direction from B	A - balloon; rocket B - air rushing from balloon; gases rushing from rocket	III (5)
Conceptual Scheme: When matter changes from one form to another, the total amount of matter remains unchanged.		
Causation (Empirical Explanation) Relations		
A makes B	A - sun B - things warm	IV (4)
	A - heat B - ice melt/ice change to water	IV (4, 9)
	A - loss of heat B - water change to ice	IV (5)
	A - heat (from sun) B - column on thermometer rise/temperature go up	IV (6)
	A - heat B - water evaporate/water change to a gas/wet things get dry	IV (8), V (9)
	A - gravity B - rain fall to the earth	V (4)

Relational Concepts	Members of the Relation	Lesson
A causes B	A - heat B - water to evaporate	IV (8, 9)
A is due to B	A - drying B - evaporation	IV (8)
A changes (causes B)	A - heat B - change from water to water vapor	V (1, 2. 7, 9)
	A - loss of heat B - change from water vapor to droples/change from water droplets to drops	V (2)
Requirement Relations		
it takes A to make B	A - heat B - ice/solid change to water/ liquid	IV (4)
A is necessary for B	A - heat B - evaporation	V (5)
Source Relations		
A comes from B	A - heat B - sun	IV (4, 6, 9)
	A - drops of water/rain B - clouds	V (3, 4, 8)
X get A from B	X - clouds A - water B - (water locations, e.g., ponds, lakes, oceans)	V (7)
A form from B	A - clouds B - water vapor in the air	V (7)
	A - droplets of water in clouds B - cooling water vapor that resulted from evaporation	V (8)
Constituency Relations		
A is made of B	A - fog B - droplest of water	V (3, 9)

Relational Concepts	Members of the Relation	Lesson
	A - cloud B - droplets of water	V (3, 9)
Locational Relations		
A goes into B	A - water vapor B - air	IV (7), V (1, 7, 9)
Effect Relations		
A pulls B	A - gravity B - drops of water/rain	V (4)
A moves B	A - wind B - clouds	V (8)
Conceptual Scheme: The universe is in constant change.		
Causation (Empirical Explanation) Relations		
A make B	A - things that get in the path of sunlight and do not let light thought B - Shadow	VI (4)
B because of A	A - rotation of earth B - change from morning to evening/day to night	VI (5, 8)
Requirement Relations		
A is needed to B	A - energy B - move a rocket away from earth	VI (2)
Source Relations		
A comes from B	A - earth's light B - sun	VI (1, 4, 6, 8)
	A - moon's light B - sun	VI (6, 8)
Locational Relations		
A reflects sunlight to B	A - moon B - earth	VI (7)

Relational Concepts	Members of the Relation	Lesson
Effect Relations		
A reflects B	A - moon B - sunlight	VI (7)
Conceptual Scheme: A living thing is the product of its heredity and environment.		
Causation (Empirical Explanation) Relation		
A makes B	A - water B - seeds grow	VII (3)
Requirement Relations		
A is needed for B	A - water B - growth of plants	VII (4)
A needs B	A - fish, people B - air	VIII (5, 6)
	A - dog B - food; water; warm, dry place to sleep	VIII (9)
Source Relations		
X gets A from B	X - mold A - food B - foods they grow on	VII (6)
X takes/gets A from B	X - gills of fish A - air B - water	VIII (5, 6)
Sequence Relations		
A comes from B	A - seeds B - plants	VII (1)
	A - fruits B - plants	VII (8)

Relational Concepts	Members of the Relation	Lesson
	A - fruits B - flowers	VII (8)
	A - birds, e.g., chicken; reptiles, e.g., turtle; insects, e.g., grasshopper; fish, e.g., salmon B - egg	VIII (1-6, 10, 11)
	A - egg B - birds, e.g., chicken; reptiles, e.g., turtle; insects, e.g., grasshopper; fish, e.g., salmon	VIII (1-6, 10, 11)
A grow from B	A - plants B - seeds	VII (1-4, 7, 8, 10)
	A - plants B - stems	VII (4)
	A - potato plants B - potato "eyes"	VII (10)
A grow into B	A - seeds B - plants	VII (1-4, 7, 8, 11)
	A - stems B - plants	VII (4)
	A - potato "eyes" B - potato plants	VII (10)
A hatches from B	A - birds, e.g., chicken; reptiles, e.g., turtle; tadpoles; fish B - egg	VIII (1-6, 10, 11)
Constituency Relations		
A Is made of B	A - nest of bird, e.g., oriole B - plant materials	VIII (12)
Use Relation		
A is/are used for B	A - part of seed B - food for new plant	VII (1)

Relational Concepts	Members of the Relation	Lesson
	A - seeds of grass plants (e.g., (e.g., oats) B - food (for humans)	VII (7)
	A - acorns B - food for squirrels	VII (9)
	A - chicken eggs B - food (for humans)	VIII (1)
	A - milk B - food for young lion/young zebra	VIII (8)
	A - seeds B - food for sparrows, gold finches	VIII (10)
	A - nests B - holding eggs and young birds that hatch from eggs	VIII (12)
Locational Relations		
A can grow on/grows on B	A - mold B - fruit/foods	VII (5, 6)
A climbs out of B	A - caterpillar B - skin	VIII (4)
Effect Relations		
A lay B	A - birds, e.g., chicken; reptiles, e.g., turtle; insects, e.g., grasshopper; fish, e.g., salmon; frog B - eggs	VIII (1-6, 10, 11)
A do not lay B	A - mammals B - eggs	VIII (7, 8, 10)
A "have" B	A - mammals B - "live" young	VIII (7, 8, 10)
A cracks B	A - bill B - seed	VIII (7, 8, 10)

Relational Concepts	Members of the Relation	Lesson
A eats B	A - caterpillar B - leaves	VIII (4)
	A - lion (adult) B - meat	VIII (8)
	A - zebra (adult) B - grass	VIII (8)
A feeds on B	A - blue jay, oriole, robin, mockingbird B - insects	VIII (10)
	A - blue jay B - acorns, nuts	VIII (10)
	A - mockingbird B - seeds	VIII (10)
	A - robin, mockingbird B - fruit	VIII (10)
A feed B	A - parents B - young robins	VIII (13)
A guard B	A - parents (robins) B - nest	VIII (13)

TABLE 7

STUDENT/TEACHER ACTION CONCEPTS

Student/Teacher Action Concepts	Types of Referents	Lesson
Conceptual Scheme: When energy changes from one form to another, the total amount of energy remains unchanged.		
Scientific Processes		
(observation), to observe, look at, study, listen to	objects, materials, animals, people, events	I (1-6), II (1-8), III (1-8)
(description) to describe, tell about	objects, animals, people, constructs, events	I (1-6), II (1-8), III (1-8)
(comparison), to compare	electrical/mechanical objects; velocities of people/machines; elephant, ant	I (2), II (3, 5)
(explanation), to explain	causes and processes of events and occurrences; justifications for descriptive statements, (e.g., giving correlated values)	I (1-4), II (1-8), III (1-5, 7, 8)
Conceptual Scheme: When matter changes from one form to another, the total amount of matter remains unchanged.		
Scientific Processes		
(observation), to observe, look at, study, feel, smell, taste	objects, materials, locations, events	IV (1-9), V (1-9)
(description), to describe, tell about	objects, materials, locations, constructs, events	IV (1-9), V (1-9)
(comparison), to compare	drops of water	V (2)

Student/Teacher Action Concepts	Type of Referents	Lesson
(explanation), to explain	causes and processes of events and occurrences; meanings of words; justifications for descriptive statements (e.g., by giving correlated values)	IV (5, 6, 8), V (2, 5-7)
(counting), to count	drops of water	IV (7)
Conceptual Scheme: The universe is in constant change.		
Scientific Processes		
(observation), to observe, look at, study	objects, organisms, locations, events	VI (1-8)
(description), to describe, tell about	objects, organisms, locations, constructs, events	VI (1-8)
(comparison), to compare	morning/evening shadows; night/day sky	VI (5, 6)
(explanation), to explain	justifications for descriptive statements (e.g., by giving correlated values)	VI (1-8)
Conceptual Scheme: A living thing is the product of its heredity and environment.		
Scientific Processes		
(observation), to observe, look at, see, study, examine, feel	plants, animals, objects, material materials, events	VII (1-11), VIII (1-15)
(description), to describe, tell about	plants, animals, objects, material materials, locations, events	VII (1-11), VIII (1-15)
(comparison), to compare	seeds, mold, leaves	VII (1, 5, 7)
(counting), to count	seeds, legs of moth, young animals (offspring)	VII (1), VIII (4, 8, 9, 13, 14)

Student/Teacher Action Concepts	Type of Referents	Lesson
(explanation), to explain	causes and processes of events and occurrences; justifications for descriptive statements (e.g., by giving correlated values)	VII (4, 9), VIII (7)
Physical Manipulations		
planting	seeds, stems, potato eye	VII (1-4, 7-10)
watering	seeds, plants	VII (3)

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